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THE CONSTITUTION OF MATTER.

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Memoir on the probable Constitution of Matter, and Laws of Motion, as deducible from, and explanatory of, the Physical Phenomena of Nature. By. J. L. RIDDELL, M. D., Professor of Chemistry in the Medical College of Louisiana; Melter and Refiner in the Branch Mint, New Orleans.

1. In all enlightened ages of the world, the studious and reflecting mind of man has sought out and entertained expanded views in regard to the physical constitution of Nature. Such views generally obtain credence, provided they harmonize with all the known natural phenomena. But it is frequently the fate of philosophical theories to fall before the progress of experimental science ; and, where such progress is great and rapid—where multitudes of new physical facts are brought to light, as they have been within a century past—it becomes a matter of deep philosophical interest, to collate and compare them with the prevalent philosophical opinions, in order to determlne whether some modification of such opinions be not required.

2. Within little more than half a century past, human knowledge has been enriched and enlarged by the entire science of electro-dynamics, by the doctrine of combining proportions in chemistry, and by great discoveries and advances in all departments of physical science. The parallax of many fixed stars has been determined, and the existence of a subtile inter-planetary resisting medium has been established. In the work of deducing, from known and special phenomena, more general laws and conditions, we have advantages, therefore, that were not possessed by Newton, Descartes, or the ancients. In the following pages I shall set forth such conclusions as I have arrived at, in calmly and carefully attempting to contribute something towards so great a work.

3. I am fully aware of the responsibility of suggesting any general views at variance with received opinions. The whole history of science shows that men are always loth to abandon the venerable philosophic opinions in which they have been educated; nothing short of the most clear and rigid demonstration brought home to the conviction, being able to shake their faith in the favorite doctrines and systems of philosophy; such is the affectionate tenacity of the human mind.

4. In giving a preliminary sketch of the views I have been induced to entertain, without preceding them with the chain of inductive reasoning and demonstration by which they have been arrived at, my object is at once to present the chief subjects clearly. That I do not build upon mere assumption, I shall take pains to make sufficiently apparent, before I finally conclude.

GENERAL PROPOSITIONS.

5. PROPOSITION I.—*Matter is any thing real, which occupies by itself, length, breadth, and thickness in Space.*

6. PROPOSITION II.—*Matter exists aggregated into spheroids or atoms, forming in respect to the dimensions of the different terms of atoms an indefinite series, probably geometrical, in which each atom is composed of an aggregation of an indefinitely great number of atoms subordinate in the series in respect to size.* Fixing the attention upon one atom of each term, they present in their relative dimensions, a decreasing or increasing series, whose ratio is indefinitely great or small, and whose number of terms above and below any assumed point, is perhaps infinite.

7. It is convenient to express the assumed material series algebraically; and if

$M=$ a visible material sphere like the sun or earth,

$\ominus=$ any ratio infinitely small,

$\not\infty=$ any ratio or quantity indefinitely great,

$\infty=$ a ratio or quantity infinitely great;

then the material series may be written in geometrical proportion thus:

$$* \; * \; * : M\not\infty : M : M\ominus : M\ominus^2 : M\ominus^3 : M\ominus^4 : M\ominus^5 : * \; * \; * : M\ominus^{\infty-2} : M\ominus^{\infty-1} : M\ominus^{\infty}$$

8. Here $M\ominus=$ a molecular atom, such as oxygen, or any other of the so called chemical elements,

$M\ominus^2=$ a more attenuated matter, probably such as an atom of the luminiferous medium,

$M\ominus^3$ &c. $=$ matter probably instrumental in producing the phenomena of attraction,

$M\ominus^{\infty}=$ the unassignable, trancendental last term of matter.

9. That the sun, earth and planets, are spheroidal masses of matter, we are in possession of sufficient proof. And that other terms of matter, though indefinitely removed in point of size, are probably spheroidal in shape, may be inferred from the nature of the forces to which matter is subject.

10. To assign a last term of matter on the scale of minuteness, would be to set limits to a subject which wears every aspect of infinity. Whatever we call great or small, cannot be absolutely great or small; only relatively so. And if there be an assignable ultimate atom of matter, no reason can be given why it should have any special limit of dimensions. Admit its existence, and then comes the natural inquiry as to its theoretical divisibility; which affirmatively forcing itself upon our conviction, we are again compelled to assent that there cannot be assigned an ultimate term of matter.

11. Should it be alleged that it is unphilosophical to invoke the agency of matter so attenuated as to elude our direct observation, I would reply that I think the existence of several material media, differing from each other almost immeasurably in respect to degrees of attenuation, or the relative sizes of their component atoms, may be logically deduced from known phenomena of nature. The impulses causing sound, travel in the ponderable and comparatively gross medium air, at the rate of 1142 feet per second. The impulses causing light, travel in the imponderable and refined medium existing between us and the sun, at the rate of 192,500

miles per second. We infer the luminiferous medium is different from, and far more refined than air, from its apparent want of weight, and the greater velocity of the impulses it transmits. For it may be conclusively shown, that the less dense and the more refined the material medium, in respect to the smallness of its component atoms, the greater the velocity with which it transmits impulsively any given momentum.

Now, as the influence causing gravity, has a velocity according, to LA PLACE, at least 100 million times greater than light, it is philosophical to infer that a still far more refined medium than the luminiferous, is the instrument of its transmission.

12. PROPOSITION III.—*Around each material atom or aggregated sphere, there lies a sort of atmosphere or medium, consisting of diffused atoms belonging to the subordinate terms in the material series.* Probably in the immediate constitution of visible bodies, as iron, gold, water, &c., the actual molecular nuclei, in reference to their intervening spaces, bear some such proportion as that borne by planetary and stellar bodies, to the immense intervening wilds of ethereal space.

13. I think the phenomena of nature warrant us to infer, that probably the intervening spaces are jointly occupied by diffused atoms belonging to the subordinate terms of matter. I do not regard such a space as others have, as being occupied simply by a homogeneous medium of attenuated matter; but as presenting at the same time an indefinite number of media, each perhaps indefinitely more, or indefinitely less attenuated than the next medium above or below in point of grossness or rarity. We are well assured that such is the actual condition of the sun, earth and planets; each being enveloped immediately by a molecular atmosphere, around which lies the luminiferous medium; and from facts innumerable, in chemistry, pneumatics and electricity, we may clearly infer such a constitution in respect to molecular atoms themselves. We cannot rationally comprehend the action of matter on matter at a distance, which often seems to be presented to us in nature, without admitting the existence of material intervening media, as the agents of such action.

14. PROPOSITION IV.—*Matter is inherently inert, or possesses what has been called vis inertiæ: by which is meant that matter can neither of itself begin to move, nor cease to move when set in motion.*

15. PROPOSITION V.—*Matter is indestructible.* Since mankind have never been able to create or annihilate matter, and since mankind have never observed these occurrences in nature; so far as human science is concerned, we may regard matter as uncreatable and indestructible.

16. PROPOSITION VI.—*Matter is inherently and necessarily possessed of no qualities, unless its extension, mobility and inertness be called qualities.*

17. To admit that inherent qualities necessarily pertain to matter, would be equivalent to denying that matter is inherently inert.

18. PROPOSITION VII.—*Motion, existing in time, (of which it is the cause and measure,) is the translation of matter through space.*

19. Though we may conceive of matter without motion, it is obvious motion can have no existence without matter. Momentum is the measure of motion. If $w=$ the mass of a moving body, $v=$ its velocity, and $f=$ its momentum; $vw=f$, The terms force and power, though often vaguely used, mean generally momentum.

20. PROPOSITION VIII.—*Motion is the source of all qualities, and the proximate cause of all phenomena which matter exhibits.* Upon this proposition I shall comment fully in the sequel.

21. PROPOSITION IX.—*Momentum is physically indestructible and uncreatable.*

22. Motion may be transferred from matter to matter, but can never, as nature is constituted, be lost or destroyed, as I shall hereafter attempt to make apparent. So where force seems to be generated it must be derived from prëexisting momentum.

23. PROPOSITION X.—*Momentum is transferable from matter to matter solely by impact or collision.*

24. The transference of motion by impact from matter to matter, is a rational effect from a rational cause; yet it often appears that this impact is mediate, not immediate, between the bodies concerned in its occurrence. This subject, the right understanding of which is so essential to further progress, I will proceed to remark upon, under the head of

IMPULSE.

25. To avoid ambiguity and circumlocution, in speaking of these subjects, where adequate terms of expression are wanting, I find it necessary to express certain ideas of frequent recurrence by algebraic symbols, which I will here for convenience again insert:

Let M=a globe of matter, as the sun or earth,
$\ominus$=any finite quantity or ratio, indefinitely small.
$\not\infty$=any finite quantity or ratio, indefinitely great.
∞=infinitely great quantity or ratio.
0=infinitely small quantity or ratio.

26. The material series of aggregated atoms, as before set forth, may be written down as a geometrical infinite series, thus: * *: M: $M\ominus$: $M\ominus^2$: $M\ominus^3$: * * * *: $M\ominus^{\infty-2}$: $M\ominus^{\infty-1}$: $M\ominus^{\infty}$. Here $M\ominus$ represents molecular matter as the chemical elements; $M\ominus^2$ the luminiferous medium; $M\ominus^{\infty}$ the transcendental first or last term of matter, or ultimate matter.

$M\ominus$ being a molecular atom, let also
[$M\ominus$ =molecular atoms;
[$\dot{M}\ominus$ =molecular atoms aggregated, or under the sensible influence of mutual attraction;
[$\overline{M}\ominus$ =molecular atoms in the gaseous or medial condition, not aggregated, because at too great a mean distance from each to feel very sensibly their mutual attractions.

27. *Impulse*, in physics, is nearly synonymous with the communication of force, or momentum, or motion, from one atom or body to another atom or body. It can best be illustrated by having recourse to an imaginary last term of matter, which to our comprehension has no assignable existence, the series being probably infinite. But if the term $M\ominus^{\infty}$ be imagined, and the individual particles considered as perfectly hard and unyielding; and if we then suppose a rod made of such particles lying in perfect contact, to extend say from New Orleans to New York, it is evident from the premises, that if a blow be given to this end of the rod with a hammer, as its substance cannot yield, the whole rod would at the same instant of receiving the blow be impelled more or less forward in space; and consequently the effect or impulse of the blow would be felt

simultaneously in New York. Thus, though the rod might not progress through space, in consequence of the blow, more than perhaps the ten-millionth part of a line, yet the force of the blow would be conveyed, and might produce an equivalent effect at the other extremity. If, instead of supposing the $M\ominus^{\infty}$ particles in contact, intervening spaces be allowed, then the progress of the impulse would require time. A medium of $[M\ominus^{\infty}$ might be supposed thus to transmit impulses of motion or momentum, without any assignable translation of the $[M\ominus^{\infty}$ medium.

28. Let us next suppose that the $[M\ominus^{\infty}$ particles are in part aggregated, so as to make a larger grade of atoms, $[M\ominus^{\infty-1}$ of far greater density than the same volume of the $[M\ominus^{\infty}$ medium. If $M\ominus^{\infty-1}$ receive from any one direction impulses from the medium $[M\ominus^{\infty}$, a length of time proportionate to its greater density must elapse before it can attain the velocity of the impinging $[M\ominus^{\infty}$ particles. Long before it would acquire this velocity, $M\ominus^{\infty-1}$ may mediately impinge upon $M'\ominus^{\infty-1}$, when its motion is gradually arrested by being gradually communicated to $M'\ominus^{\infty-1}$; momentum being successively communicated to every $M\ominus^{\infty}$ particle component of $M'\ominus^{\infty-1}$. Thus, to be in equilibrio, the velocity of impulses suffer a slower transmission, the more gross or more highly aggregated the particles composing the medium of transmission.

29. Motion, or momentum, its measure, consists in the progression of matter through space. It may be transferred impulsively from one portion of matter to another, always by the supposed actual contact of the $[M\ominus^{\infty}$ atoms. Let $w=$ a given mass of matter, $v=$ its velocity, and $f=$its momentum. By the principles of dynamics $v\,w=f$. It is theorically possible, w remaining constant, that v and f may vary from 0 to ∞. Through any assumed or given medium $[\overline{M}\ominus^{n}$, it is also theorically possible that any amount of momentum from 0 to ∞ may be transmitted impulsively. For if $w=$ the material mass of the given medium, and $vw=f$, when v becomes v', f becomes $\frac{v'f}{v}$. So when v becomes 0 or ∞, f becomes 0 or ∞.

30. The circumstances or conditions determining or making definite the velocity of impulses transmitted through any given medium, are: First, the grossness or rarity of the medium as to which term of the geometrical material series it belongs; in other words, the actual amount of matter embraced in the atoms of the medium occupying a given space: Second, the amount of momentum which the medium has to transmit in a given time. For if f be supposed constant, the impulses must travel $\not\infty$ times faster in the medium $[\overline{M}\ominus^{n}$, than in the next grosser medium $[\overline{M}\ominus^{n-1}$. Because if the tenuity of the medium be in any degree proportionate to the masses of the respective atoms, and if $w=$ the mass of $[\overline{M}\ominus^{n}$ in a given space, $\not\infty w=$the mass of $[\overline{M}\ominus^{n-1}$ in an equal space; and since $vw=f$, if w become $\not\infty w$, the equation becomes $v'\not\infty w=f$. Now since $vw=f$, and $v'\not\infty w=f$, $vw=v'\not\infty w$, and $v=v'\not\infty$. Whereas if in any medium as $[\overline{M}\ominus^{n}$, f be supposed to increase or diminish until it become af, the equation becomes $v'w=af$, and $v'=\frac{af}{w}$; whereas $v=\frac{f}{w}$ Hence $f : v :: af : v', =av$.

31. In our atmosphere we see this exemplified in the impulsive transmission of sound; it being a well known fact, that the warmer the

air—that is, the greater the amount of molecular momentum, which is essentially heat—the more rapid will be the transmission of sound. In reference to this matter, we may estimate the actual amount of molecular momentum in the air at any temperature t, expressed in degrees as units. Put $t=60^\circ$ Fahr., $t'=$ some higher temperature $v=1145$, $v'=$velocity of sound at temperature t', and $x=$ the molecular momentum sought. Now $v : x :: v' : x+t'-t$. Hence $x=\frac{vt'-vt}{v'-v}$.

ON THE INDESTRUCTIBILITY OF MOTION.

32. When we carefully scan those phenomena of the physical world which come within our cognizance, it is forced upon our conviction, that motion or momentum like matter itself, is indestructible. When, to ordinary observation, momentum seems to be destroyed or lost, it is merely diffused so as to become, to us, insensible. Friction is the transference of motion from a moving body in part to molecular atoms, and doubtless in part to the subordinate material media.

33 The assumption that motion is destructible, which may be regarded as the basis of the present received philosophical theories, is necessarily connected with the doctrine of occult inherent qualities. For if motion be constantly destroyed in nature, the universe, like a clock, would run itself down. Hence it is found necessary to derive fresh supplies of momentum, from the supposed inherent qualities of matter. The admirable consistency and harmony, which nature every where presents, when her ways are sufficiently inquired into, force upon us the conviction that every natural effect must have an adequate and rational cause. The most eminent philosopers from the days of PLATO to the present time, assent to the self-evident proposition, that mere lifeless matter is of itself inert. Yet with this truth before them, they inconsistently attempt to explain the phenomena of nature by reference to the supposed specific, occult, inherent qualities of this same matter.

34. The only really serious argument which can be adduced in favor of the destructibility of motion, may be drawn from the mechanics of collision, as set down by Wallis and others, viz: "If two perfectly hard bodies A B impinge against one another directly, they will either be at rest after impact, or will move on together as if they were one mass," (Ed. Encyc. xiii, 616.)

35. We see no perfectly hard bodies in nature but on the contrary, all bodies possessed of nearly the same elasticity within greater or less limits of compression. Yet the unassignable $[M\supset^{\infty}$ atoms, may for illustration be supposed to be perfectly hard, and as they alone can be concerned in the actual, material contact of collision, it will be well for argument's sake, to admit the truth of the before mentioned proposition, and determine its bearing in the premises.

36. Collision is the only rational and comprehensible means, by which motion can be communicated from one portion of matter to another. And those of the last term $[M\supset^{\infty}$ excepted if we suppose, as seems probable, that every atom of matter has around it an envelope of the next subordinate medium, the only real material contact can take place between $[M\supset^{\infty}$ atoms of matter. Hence, in the $[M\supset^{\infty}$ material terms alone, could there occur a loss of momentum. Now there are necessarily ∞ chances to 1, that the loss of momentum would not be

complete; inasmuch as there are ∞ chances to 1 that the impact would not be direct. Admitting the loss of momentum by the aforesaid impact among the [$M\ominus^{\infty}$ atoms, let us inquire what ratio of this loss would necessarily be felt by the molecular, and visible bodies about us.

37. Suppose that $M\ominus^{\infty-1}$ impinges upon $M'\ominus^{\infty-1}$ causing $M'\ominus^{\infty-1}$ to move through a finite distance, and then in like manner to transfer its momentum by impact to $M''\ominus^{\infty-1}$. At the time of impact of $M\ominus^{\infty-1}$ against $M'\ominus^{\infty-1}$, collision would occur among the [$M\ominus^{\infty}$ particles composing and surrounding $M'\ominus^{\infty-1}$: then a translation of $M'\ominus^{\infty-1}$ through space would ensue, in obedience to the impulse, and as $M\ominus^{\infty-1} = \cancel{\infty}\, M\ominus^{\infty}$, it would follow that $\cancel{\infty}$ times greater length of time would be occupied in this translation through the said finite space, (during which time the repetition of impulse is not necessary to maintain the motion,) than what was previously occupied by collision of [$M\ominus^{\infty}$ particles. Hence, in reference to a given momentum, f, impulsively transmitted through media, on the rational supposition that the distances between the atoms of media, differing as to the term of matter to which they belong, bear some proportionate ratio to the magnitude of the atoms themselves, there would necessarily be $\cancel{\infty}$ times as many collisions of [$M\ominus^{\infty}$, when the momentum f was traversing a pure medium of [$M\ominus^{\infty}$ matter, as when f was being transmitted through the [$M\ominus^{\infty-1}$ medium.

38. And so, if the momentum f were transversing impulsively the [$M\ominus^{\infty-n}$ medium, the number of collisions of [$M\ominus^{\infty}$ atoms (the only collisions of actual contact which could occur, upon the supposition before stated,) would necessarily be $\cancel{\infty}^{n}$ times less than in the case where f was transmitted wholly in the [$M\ominus^{\infty}$ medium. Hence, as an atom of molecular matter, (one of the chemical elements, as oxygen,) $= M\ominus = \cancel{\infty}^{\infty}$ times $M\ominus^{\infty}$, in the transmission of f momentum through air, the hypothetical loss of motion in consequence of the number of [$M\ominus^{\infty}$ collisions becomes $\frac{1}{\cancel{\infty}^{\infty}}$ of what it would be, were the [$M\ominus$ particles of air themselves the ultimate term of matter.

39. Hence, admitting the proposition, that the collision of perfectly hard bodies results in a loss of momentum, and that the transcendental ultimate [$M\ominus^{\infty}$ atoms of matter are perfectly hard; yet, if visible bodies embrace in their inherent structure a series of never-ending subordinate terms or atoms; the collision and friction of visible bodies are attended with a loss of motion$=0$, or infinitely small.

EXPERIMENTS ON CONTINUOUS AND OPPOSING IMPULSES.

40. As illustrative of this subject, I will here cite some experiments which I have often repeated, demonstrating in a striking manner, the impulsive transfer of momentum through rods of iron, without a sensible movement of the mass of iron. 1. Bend a rod of iron ten or fifteen feet in length into the form of the letter U; fix each limb firmly in a vice, or confine them otherwise; a slight blow on one end of the rod, will project with considerable force a marble in contact with the other end, the direction in which the marble is impelled being opposite to that of the blow given. 2. Arrange continuous rods so that the impulse from a single blow may be divided and traverse the same rod in opposite directions at the same instant;—and it may in like manner be shown, that opposing impulses in the same substance do not annihilate each other.

MOTION OF THE FIXED STARS.

41. Motion being indestructible, and intercommunicable among all grades of atoms and masses, we should not expect to find any matter in the universe, in a state of absolute rest. That the component molecules of visible bodies possess incessant movements of rotation and oscillation, will be rendered apparent under the heads polarity and heat. But the mass of mankind, judging from inadequate observation, find an apparent exception to this alleged universal prevalence of motion, in the so called fixed stars.

42. In contravention of this idea I would remark, that it has been demonstrated by Dr. Halley and others, that many of the so called fixed stars "have a motion of their own, which cannot arise from parallax, precession or aberration." Lalande is of opinion "that there is a kind of equilibrium among all the systems of the universe, and that they have a periodical circulation round their common centre of gravity." (Edin. Encyc. ii. 638.) Among the stars of the first magnitude which are known to move, are Aldebran, Capella, Rigel, Alpha Orion, Sirius, Regulus, Spica Virginis, Arcturus, Antares, and Alpha Lyræ. Enough is known in this department of astronomy, to leave no reasonable doubt, but that motion pertains to every visible star, which might be made apparent by accurate observations, at periods of time sufficiently remote.

43. Our sun may very properly be regarded as one of the fixed stars; and yet the observations of Argelander, published in 1837, and the still later observations and computations of Otho Struve at the Pulkova Observatory, leave no room to doubt, that the sun with the attendant planets, is at present progressing through space towards a point in the constellation Hercules, at the annual rate of near 147 millions of miles. (Vide Silliman's Jour. xlvii. 93.) It is worthy to be borne in mind, that two known circumstances conspire to veil the movements of the fixed stars from common observation: their immense distances from us, so great, that light itself sojourns for many years in its passage from the nearest of them to us; and the grandeur of their periodic movements, occupying periods of time beyond our conceptions, if commensurate with the vast and immeasurable distances in space that intervene between them. Were our sun and solar system to continue moving at the present rate (147,000,000 miles annually), and in the same direction, as before mentioned, near one million of years would elapse before we should attain the neighborhood of, or arrive opposite to, the nearest fixed star in the constellation which lies in our path.

IMPULSIVE ATTRACTION.

44. Attraction is that tendency which bodies or atoms apparently manifest to approach other bodies or atoms. Since matter is inherently inert, the tendency must proceed from an external cause. For reasons which will be subsequently given, we are warranted to infer that gravitation, as well as the attraction among the particles of liquids, etc. has its origin in the transference of momentum from media of the more refined terms of matter.

45. As with others, I cannot but regard mere matter as absolutely inert, and as any material finite body is confined within definite space and dimensions; the very idea of its inertness would preclude the notion that it could itself act; while the idea, that inert, and confined, it could act upon another

body at a remote distance from itself, is in my opinion doubly absurd. But it is perfectly rational and easy to comprehend and explain how two bodies might be impelled to approach each other in obedience to right lined impulses of motion received from a circumambient medium, whence it would necessarily follow, as bodies in respect to each other must intercept an amount of these impulses inversely proportionate to the squares of their mutual distances, the *laws* of gravitation as developed by NEWTON must be true.

46. That impulsive motion should travel in all possible directions through all possible points in space, may be reasonably deduced, from the assumptions that no assignable portion of space is devoid of matter indefinitely divided, and that motion is communicable from matter to matter without loss; for if all the sources of reflected and transmitted motion be taken into the account, nothing short of impulsive motion universally radiant will present a result commensurate with the cause. If it should be averred in opposition to these views, that this is complexity instead of simplicity, it is what nature every where presents, a complexity of harmonious results from the operations of laws of the greatest possible simplicity.

47. If, for illustration, we suppose our earth to be the only planetary or stellar body in the universe—and, further, that impulses of equal force come from all points of space in a subtile surrounding medium, it is obvious that as the effects of these impulses felt by the earth, would oppose and neutralize each other, the earth therefrom could derive no power or tendency to move. If, now, we suppose the moon to coëxist with the earth, it is clear that as they would mutually intercept from each other impulses that each would otherwise receive, they would be impelled to approach each other in obedience to those impulses which, in consequence of the interception, would not be counterbalanced.

48. Similar reasoning is obviously applicable in explanation of the molecular attraction manifested between particles in liquids, etc.; though the mainly efficient material agents bearing the coherefacient impulses may be proportionately more attenuated. But whatever may be the field or sphere of the attraction, it can observe but one law in respect to varying distances between the attracting atoms or bodies, provided it be caused by right lined intercepted impulses, as above set forth. The force of such attraction must vary inversely as the square of the distance, as I shall soon show.

GRAVITATION.

49. In respect to the comparative merits of the hypothesis of inherent gravitation, as contrasted with the doctrine of impulsive gravitation, much might be said. The former stops short and assumes an inherent inexplicable and occult quality, as residing in ponderable matter; the latter refers the phenomena to antecedent causes, rigidly in accordance with the known *vis inertiæ* of matter and the established laws of motion. If gravity be an inherent quality, what is its nature, and how may it be defined? Admitting its existence, it cannot be material; else it would necessarily be inert, like other matter: it would require to be forcibly radiated to the objects or bodies proposed to be affected by it; in which case it would necessarily produce repulsion rather than attraction. Matter may be defined, properly, to be something, anything or everything,

occupying, *per se*, length, breadth and thickness in space. And, conversely, whatever independent entity occupies space, must be matter. If gravity be not matter, then it cannot be conceived to exist in space; and if it does not exist in space, it exists nowhere, and must be nothing.

50. Gravity cannot be abstract motion or momentum, for motion or momentum obviously can have no existence separate from matter moving. Thus, if $b=$ the mass of a moving body, $v=$ its velocity, and $m=$ its momentum, by the laws of motion $bv=m$. If, then, we remove the idea of the body or call $b=0$, then in the equation, $ov=m=0$. Hence, velocity and momentum$=0$, when there be no moving body.

51. Gravity cannot be momentum necessarily inherent in matter, because we can clearly conceive of matter at rest; and, further, it cannot arise from momentum resident in the attracting body, for this momentum in being propagated to a distance, and then transferred to another body, would tend to make the bodies recede, not approach.

52. If gravity be an inherent quality, pent up and quiet in matter, how can it produce action at a distance? If it be an incessant emanation from matter in all directions, why does not matter become exhausted of it? If it emanate only towards attracting bodies, how it can it know in what direction to travel?

53. Thus it may be seen, that the admission of attraction as an inherent quality precludes all rational inquiry. Yet so far as man has studied and comprehended nature, her ways are in accordance with reason, and with the equivalent relation of cause and effect. And infinitely beyond what human researches and inquiries can ever attain to, we are, by analogy, warranted in the inference that this equivalent relation holds good.

54. Cause and effect stand in the relation of antecedent and consequent. When by collision the body A in motion, puts the body B in motion, the momentum av of A, is the cause, the momentum bv' of B, the effect. When any particular species of adequate cause, is uniformly observed to precede any particular correlative species of effect, it would be unphilosophical to refer such effect to any other species of cause. Newton says, (Principia ii. 160.) "To the same natural effects, we must, as far as possible, assign the same causes." Now as to the cause of motion, millions of clear instances are presented to every human being in the course of his life, in which motion is caused by precedent motion; and momentum produced from preëxisting momentum. Such is, and ever has been the experience of mankind; while we may challenge the production of a single instance, wherein it can be demonstrated, that motion or momentum has originated from any other cause. Is it not, then, irresistibly conclusive, that any specified motion must have been caused by an equivalent antecedent motion? And, remembering these facts, what reason have we to assume, unsupported by a single known instance, that inherent, quiescent qualities can be a cause of motion?

55. If inherent qualities have the power of originating motion out of nothing, then the mechanical problem of the *perpetual motion* is no chimera, but a promising object of pursuit. Ten thousand active minds have vainly sought in mechanical and other contrivances, for a perpetual, and inexhaustible source of momentum or power. They have not found, and cannot find it, for not in matter is the inherent power to produce motion.

56. From universal observation, then, we may set down as incontrovertible these deductions: 1, *Every present material motion has resulted from exactly equivalent antecedent motions.* And, the course of nature continuing as heretofore, II. *Every present material motion must be followed by exactly an equivalent of consequent motions.*

57. The force of momentum giving origin to the phenomena of gravity, must therefore have had an equivalent congeneric antecedent existence, essentially in the direction of the body moving in obedience to it. When we refer the origin of this force to impulses of momentum traversing a subtile medium, we assign a proximate cause, and a cause that can be comprehended and explained. Determining the relations of the assigned cause, by the most rigid mathematical analysis, we find a perfect and every way satisfactory coincidence and equivalency with the phenomena of the motions of the heavenly bodies.

58. Let it suffice for the present to determine according to what law, the force of right lined impulsive attraction, must vary in reference to variable distances between attracting bodies.

A *B*

Let A be a material spherical body in space, whose sectional area as seen from B shall $=a$. Let B represent a point upon a second body, whose distance from A shall $=d$. Now as seen from B, a may be regarded as the base of a cone, whose height $=d$, whose vertex is at B, and the diameter of whose base may here be taken as $\overline{a}|^{\frac{1}{2}}$. Since ponderefacient impulses, if unobstructed must needs come to the point B, in an equal degree from every direction, a represents that portion of the concave spherical presentation of space, from which these impulses are more or less interrupted, which in the form of square aliquot parts of the circle, can be expressed in reference to the whole. $\overline{a}|^{\frac{1}{2}}$ may be regarded as the chord of the arc subtended by A as seen from B, at distance d. If d be changed d', then

$$\left(d' : d :: \overline{a}|^{\frac{1}{2}} : \frac{d\overline{a}|^{\frac{1}{2}}}{d'}\right), \quad a|^{\frac{1}{2}} \text{ becomes } \frac{\overline{da}|^{\frac{1}{2}}}{d'}$$

Hence the apparent diameters of A, as seen from B, at distances d and d', have the proportion

$$\overline{a}|^{\frac{1}{2}} : \frac{d\overline{a}|^{\frac{1}{2}}}{d} :: d'\overline{a}|^{\frac{1}{2}} : d\overline{a}|^{\frac{1}{2}} :$$

while the apparent areas of A as seen from B at distances d and d', have the proportion $ad'^2 : ad^2 :: d'^2 : d^2$. That is, the apparent area of A as seen from B varies inversely as the square of the distance of A from B. Since the proportion of impulses which A can intercept from B, as before shown, must vary with the apparent area of A, (a representing a constant mass), it is perfectly clear that the force of impulsive attraction which the body A must indirectly exercise on B, varies inversely as the square of the distance between A and B; which result perfectly accords with nature. While if gravity be an inherent power or quality, no reason can be assigned why its force should vary according to any given law.

59. An objection to the impulsive origin of gravity might occur to some, based upon the hasty conclusion, that the impulses intercepted from

any given direction would necessarily vary as the bulk or surface of the intercepting body, and not as the mass; it being well known that bodies have weight in proportion to their mass.

60. This I admit, upon the first view, is a specious and even rational objection. But when we reflect that the nuclei of molecular bodies, probably occupy incomparably less space than what intervenes between them, this objection vanishes. Far more of the impulses may pass unobstructed through a body, than what are intercepted by the atoms immediately composing the body; so that each atom might nearly alike feel these impulses. If for sake of illustration, we assume as the body to be acted on by impulse, the immeasurable yet finite region occupied by the visible fixed stars, the stars themselves being considered as the atoms immediately composing that body, we can readily comprehend how impulses in an attenuated medium, from any assumed direction, could be felt by each individual star, without varying the assumed direction more than the smallest observable fraction of a degree.

61. As connected with gravitation, it is well to inquire whether the views advanced throw any light upon the probable cause of the wonderful coincidence generally observable among the members of the solar systems in the direction of their movements of rotation and revolution. It can be shown, that as the ponderefacient impulses must require time for their transmission through space, they would necessarily tend to give to the planets, movements of rotation and revolution, homologous with the rotation of the sun, such as we see; though it would not necessarily follow that these movements originated in this cause.

62. In respect to the homologous rotation and revolution of the members of the solar system, I will barely rehearse at present, the application of these views to show probably, why the planets revolving about the sun do not sensibly manifest the presense of the resisting medium in which they move, because their projectile movements may be sustained against this resistance by the rotary momentum in the same direction of the sun. That an interplanetary resisting material medium does exist, seems fairly deducible from observations upon the periodic revolutions of ENCKE's comet.

63. The sun rolls on his axis from west to east. The planets revolve about the sun in the same direction. Were two bodies to approach each other with the velocity of the ponderefacient impulses, they could not, while approaching, attract each other, for they could not mutually intercept these impulses in reference to each other. So, it may be shown that acceding bodies attract less, receding bodies attract more. That half of the sun's disc which is by rotation receding from the planet, exerts greater attraction, while the other half of the sun's disc, approaching the planet, exerts less attraction. The centre of the sun's attractive influence upon the planet, is therefore always maintained a little to the east of the sun's centre; a circumstance necessarily contributary to the projectile force of the planet, which is revolving around the sun from west to east. Small as this continual accession of projectile force may be, it is probably adequate to make up for the slight resistance offered by the attenuated material medium through which the planet moves. And the sun is so vast a mass that in countless ages it would not sensibly manifest, in its

own retarded movements, the vicarious influence of obstruction thus reacting upon it.

64. Touching the inapplicability of these, or any other attainable views, in explaining the origin of motion, it is proper to say that I do not attempt to inquire physically into the origin of either motion or matter. Such inquiries infinitely transcend the limits of human philosophy. Observing the matter and motion concerned in the production of particular phenomena, we may sometimes trace them both to anterior conditions, and shew whence the matter and the motion are immediately derived. We may thus, in a few instances, rationally assign a limited series of antecedent proximate causes. But the further we attempt to follow the chain, the more obscure do its apparently never-ending links appear.

65. In respect to the projectile motion in her orbit possessed by the earth, it is questionable whether we can assign a rational antecedent cause; although, as I have before explained, it is apparent how the rotation on his axis of the sun, can contribute to keep up the projectile force of the earth against a subtile resisting medium. It is sufficient for me to know that the earth and planets possess a projectile motion.

66. This motion alone would carry the earth off in a straight line, a tangent to her orbit. Were any constant force in another direction impressed upon the earth, she would compound the forces and move in at straight line, the resultant of the two; but were the second force accumulative, as a force derived from incessant impulses must be, the resultant would be a curved line, bending in obedience to the accumulative force. Now as the centripetal force operating upon the earth, tends towards the sun, by which it is indirectly caused, it is easy to see how the earth, possessed of projectile force, would revolve in an orbit about the sun. For if. r=radius of the earth's orbit, and s=sine of a small arc thereof; and if while the projectile velocity would carry the earth in a tangent parallel and equal to s, the centripetal impulses would carry the earth towards the sun the distance $r-(r^2-s^2)^{\frac{1}{2}}$, it would necessarily follow that the earth would describe a perfectly circular orbit about the sun. But if the centripetal impulses fell short of, or exceeded that effect, the path of the earth would be an ellipsis. Hence we may perceive that the theory of impulsive gravitation, perfectly accords with the mechanical phenomena presented by the solar system in the revolutions of the planets.

MOLECULAR REPULSION.

67. Molecular repulsion is that manifestation of molecular force which in effect gives the integrant particles of a mass or medium a tendency to recede from each other. Its measure is the amount of molecular momentum; its usual proximate cause, the mutual mediate collision of molecular atoms. Repulsion in respect to any medium, is the mutual reaction by impulse, of the integrant particles of that medium upon themselves. All the molecular momentum they possess, must directly contribute to repulsion. Unlike impulsive attraction, where momentum is transferred from the more attenuated to the incomparably less attenuated atoms, as from impulses of $[\overline{M}\ominus^{n}$ communicated to atoms of $[M\ominus^{n-m}$. Assuming a given surface to be overlaid with atoms of $[\overline{M}\ominus^{n-m}$ the proportion of the impulses which would be transmitted through the surface unobstructed, to those which would be communicated to the $[\overline{M}\ominus^{n-m}$ particles. would be as ∞^{m} to 1. That is, incomparably more would pass, than would be retained. Hence, as in nature, impulses are necessarily

directed towards all points, the impulsive attraction which would be induced between $M \circ^{n-m}$ and $M' \circ^{n-m}$ would vary in force inversely as the square of their mutual distance, as I have before demonstrated. (¶ 58.) But not so with the force of repulsion.

LAW OF MOLECULAR REPULSION.

68. I will first demonstrate what the law of molecular repulsion for varying distances must be theoretically, and then adduce facts and experiments in confirmation of the law so deduced. We will suppose the molecular momentum of a given cubic mass or medium m^3, to remain constant; in other words that in number the oscillating atoms remain the same, and continue to possess individually the same mean velocity of oscillation; the normal force of repulsion may be measured by the molecular momentum offering itself outward from a side of the cube, m^2; where n particles present themselves at t intervals of time, with v mean velocity. Let m become m', m^2 becomes m'^2, and m^3 becomes m'^3. Now, since each particle has a different space through which to oscillate, the intervals of return to any particular point become $\left(m : m' : : t : \frac{m't}{m} \right)$, $\frac{m't}{m}$; and the number of particles presenting themselves upon a surface $= m^2$ becomes $\left(m'^2 : n : : m^2 : \frac{m^2 n}{m'^2} \right)$, $\frac{m^2 n}{m'^2}$.

It is obvious, v remaining constant, that the momentum (or repulsion) offering in a given time, upon a given surface, must depend directly upon the number of particles presenting, and inversely upon their intervals of return. Hence, as $\frac{n}{t} =$ the normal force of repulsion on m^2 surface,

$$\frac{nm^2}{m'^2} \div \frac{m't}{m} = \frac{nm^3}{tm'^3} =$$

the force of repulsion upon an equal surface, when m, the linear measure of the supposed cube, becomes m'. It is also clear that the mutual distance d, of the integrant particles, must vary directly with m. $m : m' : : d : d'$. Hence the force of repulsion at distance d : to force of repulsion at distance $d' : : \frac{n}{t} : \frac{nm^3}{tm'^3} : : 1 ; \frac{m^3}{m'^3} : : m'^3 \cdot m^3 : ;$ or substituting d and $d' : : d'^3 : d^3$. Therefore, *the effective force of molecular repulsion among atoms, as exercised in a given time, through a given plane varies inversely as the cubes of their mutual distances.*

69. I will now proceed to compare the foregoing theories with the actual results of experiment. Elastic fluids, as air, occupy an amount of cubic space, exactly proportionate to the degree of pressure applied to them. Under a pressure of ten atmospheres ten cubic inches of air become one. Here the pressure is increased from 15 to 150 lbs. to the square inch. And so, proportionately, for other degrees of pressure.

Here let $d =$ mean molecular distance at pressure $p =$ repulsion r;
$d' =$ mean molecular distance at pressure $p' =$ repulsion r';
wherefore $d^3 =$ volume of elastic fluid at pressure p,
and $d'^3 =$ volume of elastic fluid at pressure p'.

Now since the volume varies inversely as the pressure, $p : p' : : \frac{1}{d^3} : \frac{1}{d'^3}$;

and $r = p$, and $r' = p'$, $r : r' : : \frac{1}{d^3} : \frac{1}{d'^3}$.

That is, from the most rigid experiments on the influence of pressure upon the volume of elastic fluids, it is mathematically deducible that *the force of repulsion varies inversely as the cubes of the molecular distances*, as before set forth.

CAUSES WHICH GIVE DEFINITE VOLUMES TO LIQUIDS.

70. Since it is demonstrable as I have shown, that the force of right lined impulsive attractions varies inversely as the square of the distance; (¶ 58, 136); and the force of molecular repulsion varies inversely as the cube of the distance; (¶ 68); the causes which give definite volume of liquids, are clearly apparent. For if great pressure be applied to force the integrant molecules nearer each other, the pressure will be met and equalled by the consequent excess of the repulsive over the attractive force; while any temporary cause operating to produce expansion or recession of the molecules from each other, would have to encounter a comparatively increasing force of attraction; which, when the expansive force be removed, would bring the molecules back to their former equilibrium.

FORCE OF MOLECULAR ATTRACTION BETWEEN ADJACENT SURFACES OF WATER.

71. In fluids where the molecules are mutually so remote as not to be sensibly influenced by polaric attraction and repulsion, and where consequently, they are free to move past each other and take new positions, right lined impulsive attraction must be the only bond of union among them. This force, in respect to varying molecular distances, necessarily varies inversely as the squares of those distances, as shown in ¶ 136. With the view of demonstrating the degree of this force, perhaps no better data can be made use of than the rate at which water is compressible. For one atmosphere of pressure (15 pounds to the square inch), water suffers a compression of 513 ten millionths of its volume. It is proper to observe, that if in effect the intensity of the molecular forces vary from an increase or diminution of the $[\overline{M}\circ^{2}$ medium (¶ 107); or if the forces of polaric attraction and repulsion (¶ 127,) be sensibly operative in liquids, conjointly with those which I have in this memoir designated as molecular, then the following formulæ and consequent numerical results, (¶ 71, 74, 76, 98,) will require corresponding modifications.

Let $p=15$ lbs. pressure per square inch,
$a=.0000513$,
$x=$normal force of molecular attraction $=$normal force of repulsion.

If the normal volume of water be 1, the volume will be, during pressure, $1-a$.

$$1 : x :: \frac{1}{1-a}\Big|^{\frac{2}{3}} : \frac{x}{1-a}\Big|^{\frac{2}{3}} = \text{abnormal force of attraction. (¶ 136.)}$$

$$1 : x :: \frac{1}{1-a} : \frac{x}{1-a} = \text{abnormal force of repulsion. (¶ 68.)}$$

Now, from the conditions of abnormal equilibrium, we have the equation

$$\frac{x}{1-a} = \frac{x}{1-a}\Big|^{\frac{2}{3}} + p.$$

Putting $c=\overline{1-a}|^{\frac{2}{3}}=0.999966$, and reducing the equation,

$$x=\frac{cp-cpa}{c+a-1}=866{,}978 \text{ lbs.}$$

Hence the usual force of molecular attraction among the particles of water, as exercised perpendicularly to any imaginary plane, cannot exceed 866,978 lbs. per square inch, as a maximum.

CAPILLARY ATTRACTION.

72. When one end of a tube of small bore with both ends open, is dipped into a liquid capable of wetting it, the liquid ascends in the tube to a height inversely proportionate to the periphery of the bore. From very many experiments made, I could observe no variation of the height of water and aqueous solutions referable to the chemical or mechanical nature of the tube, provided it be completely wetted by the liquid; from which I am inclined to infer that the limit of ascent in a tube of given diameter is solely determined by the molecular forces in the liquid itself. The weight of liquid thus raised is always directly proportionate to the periphery of the bore.

73. The molecules of liquids, wetting solids by contact, must come within the influence of the polaric attractions of the atoms or molecules of such solids. These forces, as exercised between the highest and last row of liquid particles in the capillary tube, and those particles of the solid composing the tube which lie obliquely a little higher still, must alone be essentially effective in sustaining the capillary column of liquid, in opposition to the weight of the same. The upper extremity of the liquid column presents a concave surface; and the very highest portion of the liquid, sustaining as it does the column below by attraction, must necessarily possess less than a normal density. Fortunately we may approximately determine the limits of this decrease of density, from the laws of molecular forces; and thus will we posssess data for estimating the minimum amount of space occupied by a single particle of water; a most curious physical problem, the definite solution of which has never that I am aware, been heretofore attempted.

DEGREE OF MOLECULAR ATTRACTION OPERATIVE IN PRODUCING AND LIMITING THE CAPILLARRY ASCENT OF WATER.

74. If $d=$ the normal distance $=1$, between adjacent atoms of water, when the forces of molecular attraction and repulsion are supposed to be equal, then (¶ 70) $\frac{1}{d^2}=\frac{1}{d^3}$. If d increase and become d', then $\frac{1}{d'^2}$ is greater than $\frac{1}{d'^3}$; and the expression $\frac{1}{d'^2}-\frac{1}{d'^3}$, will have a maximum value, as may be shown by the differential calculus, when the value of d', is taken at 1.50. At this distance no other forces intervening, there would exist a maximum surplus of attraction over repulsion. If the normal attraction and repulsion at distance d, be each$=1$; the force of attraction at distance $1.5=0.444$, the force of repulsion$=0.296$, and the difference or surplus of attraction$=0.148$. Now it necessarily follows from the laws of equilibrium, that this surplus of attractive force, when developed at the upper extremity of a liquid column sustained as before described in a capillary tube, must be exactly counterbalanced by its cause, the weight of the liquid column. And as I have shown (¶ 71) that the normal forces of cohesion among particles of waters cannot exceed 866 78 lbs. to the square inch, so here by proportion we infer (1 : 866 978 :: 0.148: 128 289.77) that the operative force in the capillary attraction of water cannot possibly exceed 128 289.77 lbs. per

square inch. It probably falls much short of this, and should be determined experimentally. With present data no other maximum can be certainly assigned. (Vide ¶ 136.)

EXPERIMENTAL DETERMINATION OF THE CAPILLARY ASCENT OF WATER.

75. Finding the experimental results given by writers on this subject, discordant and irreconcilable, I determined to make experiments with extraordinary care. By means of a tinsel wedge 5.18 inches long, and 0.15 at bore, tapering to a point, I determined the mean diameter of a very even bore flint-glass quill tube, to 0.432 inches; in this, distilled water rises to the height of 0.91 inches, the thermometer standing at 62° Fahr. From these data it can be inferred, that one linear inch of the periphery of a glass tube, (or in the same ratio, if the tube be smaller), will sustain by capillary attraction .00035441 lbs. avoirdupois of water.

APPROXIMATIVE DETERMINATION OF THE MINIMUM DIMENSIONS OF SPACE OCCUPIED BY A SINGLE PARTICLE OF WATER.

76. Put e=.00035441,=the force of capillary attraction in water per linear inch (¶ 75) in lbs. av.

b=128289.77=the force of capillary attraction in water per square inch (¶ 74) in lbs. av.

x=the thickness of space in parts of an inch, occupied by the extreme highest portion of water in a capillary tube, necessarily consisting of a single row of aqueous molecules.

Now, since it is obvious that $bx=e$, $x=\frac{e}{b}$ =.000000 002762, of a linear inch, while x^3=.000000 000000 000000 000000 02105, which is certainly as small as, if not smaller than, the cubic space in decimals of a cubic inch, occupied by a single molecule of water. That is, the nucleus and envelope of a single molecule of water, occupy as an assignable minimum so little space that nearly 200 quatrillions of them are contained in a cubic inch of water; and the weight of a single one not far from six quatrillionth parts of a grain. To assist the mind in attempting to conceive these numbers, let us compare the molecules of water to grains of common black writing sand, of which a single grain is barely visible to the naked eye at the distance of two or three feet; and of which about 1,000,000 in number are contained within the space of a cubic inch. Did each molecule of water of the limits of size assigned, occupy as much space as a grain of this sand, the 200 quatrillions before mentioned as being contained in a cubic inch of water, would necessarily fill a space so large, that if in the form of a cube, this cube would be near 95½ miles across.

LAWS OF MOTION, CONSEQUENT UPON THE DIRECT COLLISION OF ELASTIC BODIES.

77. To explain the mechanism of many natural phenomena, it is essential that the results of the collision of elastic bodies, should be thoroughly understood. In works accessible to me, on mechanics, this subject is treated on the general assumption that motion is destructible, and therefore in a manner which seems complicated, inconvenient, and objectionable. I shall deal briefly with the subject, my principal object being to give certain dynamical formulæ, of which I may make subsequent use.

78. PROPOSITION I.—If two perfectly elastic spheres of equal mass

approach with equal velocity and impinge directly upon each other, they will mutually interchange momenta and directions of movement, and recede with the same velocity.

79. PROPOSITION II.—If two perfectly elastic spheres of unequal mass, approach each other with equal momenta, their velocities being inversely as their masses, after direct impact they will recede with equal momenta, each with its first velocity, as before impact. In the two foregoing propositions the centre of gravity between the bodies is supposed to be at rest.

80. PROPOSITION III.—In reference to two perfectly elastic bodies before and after collision, their centre of gravity is either at rest, or moves uniformly in the same direction, both before and after collision.

81. PROPOSITION IV.—In all cases of collision, the two bodies approach their centre of gravity with equal momenta.

82. PROPOSITION V.—Two bodies separating elastically after collision always recede from their centre of gravity with equal momenta.

83. In accordance with the preceding propositions,

A . C B

Let $A=$ an elastic body moving uniformly towards C.
$B=$ an elastic body, also moving uniformly towards C, where it is to meet A in direct collision.
$C=$ centre of gravity of A and B, moving uniformly, both before and after collision towards A.

Put $a=$ a mass of A,
$b=$ a mass of B,
$v=$ velocity of C,
$h=$ velocity of A before impact,
$h'=$ velocity of A after impact,
$n=$ velocity of B before impact,
$n'=$ velocity of B after impact.

It follows that before impact
$h+v=$ velocity of A towards C,
$n-v=$ velocity of B towards C.

By PROP. IV. $ah+av=bn-bv$ - - - - - - (1)

$$v=\frac{bn-ah}{a+b} \quad \text{. . . . . .} \quad (2)$$

So likewise, after impact,
$h'-v=$velocity of A from C,
$n'+v=$velocity of B from C,

and by PROP. V. $ah'-av=bn'+bv$. - - . - (3)

Forming an equation from the first members of (1) and (3), $a\,h'-av=ah+av$

$$h'=h+2v \quad \text{- - - - -} \quad (4)$$

Forming an equation from the second members of (1) and (3), $bn'+bv=bn-bv$

$$n'=n-2v \quad \text{- - - - - -} \quad (5)$$

84. The formulæ, (4) and (5,) are rendered far more simple than those usually given, in consequence of the introduction of v, (2,) as the velocity of the centre of gravity; yet they will be found rigidly correct, and universally applicable to all possible cases coming within the conditions proposed.

85. By these formulæ it may be shown, as I have demonstrated by

actual experiment, that when a large elastic body in motion, impinges upon a very small one at rest, the large one communicates almost twice as great an absolute velocity to the small one, as the velocity possessed by itself.

ON THE DENSITY OF GASES, AND EQUIVALENT VOLUMES

86. A gas or aerial body is made up of molecules, at so great a mean distance from each other, as not very sensibly to manifest, in the phenomena they present, their mutual influence of attraction. The force of molecular repulsion is equilibrated by external pressure, which is ordinarily a consequence of the weight of the atmosphere. By the word molecule, I here mean the $M \circ$ nucleus, whether simple or compound, which is central to a comparitively extensive envelope of $\lceil \overline{M} \circ^2$ matter.

87. We will first determine the necessary laws of distribution in space, pertaining to gaseous nuclei of different masses, under like circumstances of pressure and temperature. Let us suppose the gas O, a single molecule of which possesses the mass o, to be confined in a thin flexible impermeable bag ; and that this bag is surrounded by the gas H, a molecule of which has the mass h, It is required to determine the relative mean molecular distances at which the molecules of O and H will be in equilibrio.

Put x=molecular distance in H,
y=molecular distance in O,
v=mean molecular velocity of oscillation in H,
v'=mean molecular velocity in O,
S=a given amount of the surface of the bag, separating O from H.

It will follow that

$\frac{1}{x^2}$=relative number of H molecules presenting themselves on S.

$\frac{1}{y^2}$=relative number of O molecules presenting themselves on S.

$\frac{h}{x^2}$=mass of H presenting on S.

$\frac{o}{y^2}$=mass of O presenting on S.

Now in order that the pressure may be equal within and without the bag, the molecular momentum reciprocally transmitted through S, in a given time, must be equal from both directions. Therefore (vide ¶ 90, 91.)

$$\frac{v^2h}{x^2}=\frac{v'^2o}{y^2} \quad \text{- - - - - - - - - - - - - - -} \quad (1.)$$

But when h separates impulsively from o, the impact having occurred mediately through S, h and o must possess equal momentum. (Collision, *Prop.* V, ¶ 82.) Therefore $v^2h=v'^2o$ - - - - - - - - - - - (2)

Hence, dividing (1) by (2), $\frac{1}{x^2}=\frac{1}{y^2}$ and $x=y$ - - - - - (3)

88. It is, therefore, clear that different gases in separate containers, under like circumstances of pressure, temperature, etc., are necessarily so constituted, dynamically, in respect to space, that an equal amount of space will contain an equal number of molecules of each. Hence the density of a gas is a direct measure of its relative molecular weight.

MECHANISM OF GASEOUS DIFFUSION.

89. It has been experimentally established that gaseous bodies differing in density, such as oxygen, nitrogen, hydrogen, watery vapour, ammonia, carbonic acid, etc., possess the power of spontaneously commingling with each other so as to become equally diffused throughout. The only explanation ever offered, deserving a present notice originated with Mr. Dalton, of Manchester, who regarded any one kind of gas as a vacuum in respect to any other kind of gas; which implies that repulsion is not exercised between heterogeneous gaseous molecules. (*Turner's Chemistry, London edition*, 1842, *p.* 213.) This assumption in its full extent, is not only inexplicable, but is untenable. For as repulsion must be the mere physical effect of collision, it must ensue when mass impinges upon mass, or molecule on molecule, regardless of any other consideration.

90. I have shown (¶ 88) that under like circumstances, the same amount of space must contain the same number of any kind of gaseous molecules. As before (¶ 87),

Let o=mass of a gaseous molecule, O,
h= mass of a gaseous molecule, H,
v= mean velocity of oscillation of h,
v'=mean velocity of oscillation of o.

Now, since the molecular distances in O and H are equal, we may safely assume that o and h oscillate through distances nearly equal. It would hence follow that if we assume

av=number of oscillation of h in time t,
then av'=number of oscillation ot o in time t.

The momentum estimated for the time t, will necessarily be directly as the mass, the velocity and the number of oscillations. Therefore o will have a momentum in the time $t = o \times v' \times av' = oav'^2$, - - - - - - - (1)
And so for h, the momentum for the time t, will be $= h \times v \times av = hav^2$. (2)
As before explained these momenta must be equal. Therefore, making (1)=(2), we have $ov'^2 = hv^2$. - - - - - - - - - - - - - - (3)
Converting (3) into proportion, $v^2 : v'^2 :: o : h$, wherefore $v : v' :: \frac{1}{\sqrt{h}} : \frac{1}{\sqrt{o}}$ - - - - - - - - - - - - - - - - - - - (4)

91. Hence it appears that under like circumstances, the mean velocity of molecular oscillation, varies inversely as the square root of the molecular weight or mass; or what amounts to the same thing, inversely as the square root of the density of the gas. That such is the fact, Mr. Graham has placed beyond a doubt, by experiments upon the velocity of gaseous diffusion through porous septa.

92. I have prepared the following table as relevant to the subject.

I. NAMES OF GASES.	II. COMBINING PROPORTIONS.	III. RELATIVE DENSITIES.	IV. SQUARE ROOT of density, = an approximation towards the comparative length of time occupied in a single molecular oscillation.	V. RECIPROCAL of the square root of density, = relative mean molecular velocity.
OXYGEN	$8 \times 2 = 16.00$	16.00	4.000	0.250
NITROGEN	14.15	14.12	3.757	0.266
HYDROGEN	1.00	1.00	1.000	1.000
VAPOUR OF WATER	9.00	9.00	3.000	0.333
AMMONIA	$17.16 \div 2 = 8.57$	8.56	2.925	0.342
CARBONIC ACID	22.12	22.12	4.708	0.212
COMMON AIR	MEAN 14.50	14.50	3.808	0.262

As to column IV, approximating the comparative length of time occupied in a single molecular oscillation, since the centres of the molecules would at each impact approach more or less near each other, dependant in some ratio upon their velocities, a small correction should be made, derived from some direct function of column V.

93. The dynamical condition of a gas, when composed of homogeneous molecules, must necessarily be such that the molecular oscillations are isochronous, meeting each other in collision at equal intervals of time, and with equal momentum. But this harmony and regularity would be disturbed, by offering in immediate contact, heterogeneous gases, differing in molecular mass or density. It can be easily seen that the dynamical equilibrium would be disturbed, in consequence of the different periods of molecular oscillation, as set forth in column IV of the table (¶ 92.)

94. In exemplification, suppose a quantity of hydrogen gas transferred into a jar containing carbonic acid gas, standing over water. Most of the hydrogen would immediately ascend and temporarily occupy the upper part of the jar, by virtue of its relative levity; its density being 1, that of carbonic acid 22.12, which is also the relation of their molecu-

lar masses (columns II, III,). These numbers may be designated by h and c. Let o=the velocity of $h=1$, and v'=the velocity of $c=0.212$, as per column V. Their periods of oscillation are nearly for $h=1$, for $c=4.708$. Before mixture h and c possess in equal time equal momentum (¶ 87). But immediately after being presented to each other, a little reflection will render it apparent, that such cannot be the case. For though $hv^2 = cv'^2$ (¶ 90,) yet when h and c come in collision, they react on each other at that instant with the momenta hv, and cv', the momentum of c being $\frac{v}{v'}$ = about five times greater than the momentum of h. Hence the momentary collision of h on c, does not prevent c from pushing itself forward into the hydrogen. So on the other hand, if c' is oscillating towards the carbonic acid, the superior velocity of h' enables h' to follow c' into the carbonic acid, beyond the normal point of collision for homogeneous gases. In a similar way it can be shown, that a stable dynamical equilibrium cannot be attained until the molecules of carbonic acid and hydrogen are equably diffused throughout each other.

95. Hence we may deduce, that the cause which produces the equal commingling of different fluids, is to be found in the mechanical laws of collision; and that it depends essentially upon the different masses, or amounts of matter, naturally embraced in the different molecules. It must be apparent to any one, after a little reflection, that the commingling of different kindred liquids is produced in a closely similar manner.

96. That carbonic acid, the density of whose molecule is greater than that of nitrogen, in the ratio of 22.12 to 14.12, should diffuse itself into the atmosphere in opposition to gravity, may at the first view seem strange. But when we consider the velocity of its molecular motion, 923 feet per second (¶ 97), and take into the account the transcendentally small absolute weight of a single molecule, 2.45 times that of the molecule of water, (¶ 76) and therefore near 15 quatrillionth parts of a grain ; we can readily appreciate the inefficiency of gravity in the way of confining it to the lowest stratum of the atmosphere.

VELOCITY OF SOUND THROUGH GASEOUS MEDIA.

97. It has been determined that air transmits sound ordinarily at the rate of 1142 feet per second, which must be the mean molecular velocity in air, say at 60° Fahr., and 30 in. barometer. From the last column (V) given in the table above, it is easy to determine approximately the velocity with which sound would travel through the several gases named, under like circumstances of temperature and pressure, expressed in feet per second, with the following results ;

	RESULTS OF THE ABOVE CALCULATION.	From Edin. Encyc. I. 115. Results set down in Campbell's Table.
In Air, as quoted,	1142	1130
Oxygen,	1089	1064
Nitrogen,	1159	1149
Hydrogen,	4358	3899
Watery Vapour,	1451	
Ammonia,	1490	
Carbonic Acid,	923	922.

TIME OCCUPIED BY A SINGLE MOLECULAR OSCILLATION IN AIR.

98. We have data, I think, which enable us to determine the minimum period of time in which a molecule of a given medium, as air, say at 60° Fahr., and 30 in. barometer, performs one of its orbital oscillations; the interval elapsing between its departure from, and near return to, any assumed point. Thus;

Let v=1142 feet=13704 inches=the velocity of sound in air, as above, per second of time.

m=14.5÷9=1.611=the molecular mass of air, that of water being assumed as unity. (¶ 92, II.)

s=815.=the density of water, that of air being assumed as unity.

x^3=.000000 000000 000000 000000 021=the cubic space occupied by a molecule of water in parts of a cubic inch. (¶ 76.)

It can be seen that hence $\overline{msx^3}|^{\frac{1}{3}}$=.00000002925 of a linear inch = the molecular distance in air, or the central mean distance between the molecules of air in parts of an inch, which is 10.44 times greater distance than that between the molecules of water. Now by proportion,

$$\frac{v}{2} : 1 :: \overline{msx^3}|^{\frac{1}{3}} : \frac{\overline{2msx^3}|^{\frac{1}{3}}}{v} = .000000\,0000042686 \text{ decimals of a second}$$

of time,= the period of oscillation sought. That is, a molecule of air cannot perform, in one second of time, more than four billions of complete oscillations, as a maximum.

NATURE OF HEAT.

99. By induction from known facts, and established principles, it may be inferred, as I hope hereafter to show:

100. I. That *heat* or *temperature* is that appreciable condition of ponderable bodies, immediately and mainly dependant upon the greater or less intensity of molecular oscillation; and subordinately upon the luminiferous medium, ($\overline{M}\circ{}^2$).

101. II. *Sensible heat* or temperature is referable to that portion of the molecular momentum, mutually interchangeable, and incessantly interchanged among adjacent bodies, such as solids, liquids and gases. Or more specifically, in adjoining media of the same temperature, sensible heat is the measure of intensity of the molecular momentum reciprocally antagonized by each others pressure.

102. III. *Absolute caloric* may be properly defined to imply all the molecular momentum possessed by a body.

103. IV. *Specific heat* is the quantitative relation which the absolute caloric has to the sensible heat.

104. V. *The absolute zero of cold*, is that imaginary condition of temperature in a body, whose molecules are supposed to be wholly divested of oscillatory movements among themselves; and though by calculation the absolute zero may in certain bodies be definitely assigned, as I shall hereafter show; yet as nature is constituted, such a condition is practically unattainable.

105. VI. Contributary impulses from the luminiferous medium ($\overline{M}\circ{}^2$) may increase temperature, by increasing molecular momentum; and conversely, temperature may be lessened by the transfer of momentum from molecular ($\overline{M}\circ$), to luminiferous atoms ($\overline{M}\circ{}^2$). This proposition involves the doctrine of radiant caloric.

106. VII. When the volume of a body becomes enlarged, in consequence of an increase in the amount of its molecular momentum, the $\overline{M}\ominus^{2}$ envelope of each $M\ominus$ molecule, must tend to acquire concurrently, an additional quantity of attenuated matter from the surrounding $\overline{M}\ominus^{2}$ medium, in obedience to laws analogous to those of pneumatic equilibrium. And conversely, when the volume of a body becomes less from diminished molecular momentum, it would tend to contain within its limits a smaller amount of said medium.

107. Any considerable accession or diminution of $\overline{M}\ominus^{2}$ matter, probably in effect sensibly modifies the laws of molecular attraction and repulson.

PROBABLE CAUSES OF THE LUMINOSITY OF THE SUN.

108. The continuous supply of light and heat furnished by the sun, for indefinite ages past, with untiring energy, and without symptoms of abatement, has ever excited the wonder of mankind. Terrestrial fires, which we are apt to consider analogous, require a continual and bountiful supply of fuel, or they go out; while the sun, more brilliant and efficient, beyond the power of imagination to compare, shines on from century to century with undiminished mass, and without any apparent contributions of matter from abroad.

109. Hence the sun cannot, in the proximate causes of its luminosity, be analogous to terrestrial fires, nor can its surface or mass be undergoing the process which we ordinarily call combustion. Yet as heat and light are but sensible manifestations of material motion, the immediate causes of the heat and light emanating from the sun, can I think be demonstrated in a rational and tolerably satisfactory manner.

110. In attempting this demonstration, I shall make use of the following proportionate data. (Vide Hassler's Logarithms, page 11, and Bowdwitch's Laplace, III. 108.)

Mass of the sun - - - - -	329630.	$=s.$
Mass of the earth - - - - -	1.	$=e.$
Mass of the moon - - - - -	0.0146	$=m.$
Surface of the sun - - - - -	12486.	$=S.$
Surface of the earth - - - -	1.	$=E.$
Surface of the moon - - - -	0.0742	$=M.$

Ratio of the surface to the mass, in the sun$=\frac{s}{S}=26.4$; - (1)

In the earth$=\frac{e}{E}=1$; - - - - - - - - - - - (2)

In the moon$=\frac{m}{M}=0.196$ - - - - - - - - - - - - (3(

111. Our only measure of the mass of a heavenly body, is its efficiency in intercepting the ponderefacient impulses, as determined by its consequent power of gravitation. The amounts of ponderefacient momentum retained by the sun, earth, and moon, are respectively in the proportions *s*, *e*, *m*. If we assume a definite equal amount of surface, *a*, on each of these bodies, it is obvious that through this surface there would be transmitted equal amounts of ponderefacient momentum, much of which might be transmitted through the body without being transferred to its mass. But of the amount intercepted by the body, and received by its mass, there would enter through *a*, proportionately,

For the sun, (1), - - - - - - - - 26.4 ,
For the earth, (2), - - - - - - - - 1. ,
For the moon, (3), - - - - - - - - 0.196.

112. If the bodies were of equal density, and similar shape, these numbers would vary directly as the diameter. For if d, d', d''= their diameters, nd^2, nd'^2, nd''^2 will express their surfaces, and cd^3, cd'^3, cd''^3 their masses. The expressions (1), (2), (3,) would then become $\frac{cd^3}{nd^2}=\frac{cd}{n}$, $\frac{cd'^3}{nd'^2}=\frac{cd'}{n}$, $\frac{cd''^3}{nd''^2}=\frac{cd''}{n}$; and their ratios d, d' and d''.

113. Since momentum is indestructible, it is clear, that to maintain equilibrium, there must emanate from the aforesaid bodies through the space a, on the surface of each, as much momentum in a given time as that received, as expressed in (1), (2), (3). And it is obvious from the induced gravitation and other phenomena, that the emanating momentum does not wholly attach itself to the ponderefacient medium in which it came; but finds exit in part in the luminiferous medium more gross, $\overline{M}\circ^2$; and doubtless partly in media more attenuated than the ponderefacient.

114. Thus it is apparent, that in equal time, through a given and equal amount of surface, there is sent forth into open space, near $26\frac{1}{2}$ times more momentum from the sun than from the earth.

115. We may now institute a collateral inquiry, as to the probable temperature of the sun's surface, as compared with that of the earth, which may for this purpose be assumed at say 60° Fahr. In prosecuting this enquiry, we must necessarily admit certain pure assumptions, since we have no certain knowledge of the nature of the molecular constitution of the sun, nor of the ratio of the momentum alluded to, possessed by the sun's molecular atoms. We will assume that the nucleus of the sun, is immediately invested by an aerial atmosphere as dense as ours at the level of the sea; and that the molecular atoms at the surface of the sun's nucleus, possess two-thirds as much as the molecular atoms at the earth's surface, of the whole ponderefacient momentum to be disposed of, respectively through equal surfaces on the sun and earth.

116. Let 1=the volume occupied by air near the level of the sea, at 60° Fahr.;

$r=\frac{1}{480}$=the increase of volume acquired by the same air when heated to 61° nearly;

x=amount of latent and free heat, possessed by said volume of air at 60°=the amount of molecular momentum, expressed in reference to 1° (or the momentum acquired in being heated from 60° to 61°) as unity.

Ratio of molecular distances=1, (at 60°) : $\overline{1+r}|^{\frac{1}{3}}$, (at 61°).

117. Now since the pressure of the atmosphere which antagonizes the force of repulsion, may be considered constant: we may derive an equation involving x, in the following manner:

$1 : x :: \frac{1}{1+r} : \frac{x}{1+r}$=the repulsive efficiency of x at 61° (¶ 68), and

$\frac{x}{1+r}+1=x$.

Hence, by reducing the equation, $x=\frac{1+r}{r}=481$. Hence, air near the

level of the sea, at 60°, entertains molecular momentum equivalent to 481° Fahr. of absolute heat. Hence the absolute zero of cold for such air is near —421° Fahr. Though I do not consider this result as rigidly true, yet it is certainly a sufficiently close approximation for our present purpose. It would consequently follow, from the preceding assumptions, and from (1) and (2), that $\frac{481° \times 26.4 \times 2}{3} = 8465°$ nearly = the molecular momentum of air at the surface of the sun, expressed in degrees Fahr., and its temperature would be near (8465°—421°=8044°) 8044° Fahr.; a far higher degree of heat than we have any instrumental means of measuring, and at which all known substances would doubtless exist in a condition of intense incandescence or luminosity.

118. The two assumptions admitted into these calculations may be varied widely within the bounds of probability, without essentially changing the result.

119. In like manner it might be rendered probable that the surface of the moon is intensely cold. For even admitting it has as dense an atmosphere as the earth, while in truth it is questionable whether it has any, it would follow, as before shown in reference to the sun, that its surface temperature, due to necessary inherent warmth alone, would be probably near (481°×0.196 (3)—421°=—327° nearly)—327° Fahr. It is presumable, however, that the influence of the sun maintains the moon's surface at a somewhat higher temperature than this.

120. In respect to the luminosity of the sun, having demonstrated that an exceedingly high temperature necessarily pertains to that body, as a consequence of its enormous mass, it only remains to inquire into the probable condition of the electric or luminiferous medium, $\overline{M}\circ^2$, pervading its structure, and immediately surrounding its surface. It is first proper to determine, whether that medium probably possesses a greater degree of density in and about the sun, than in and about the earth. That its atoms are more gross than those of the ponderefacient media, I have already rendered apparent. They must, therefore, tend to amass themselves around the heavenly bodies, in obedience to impulsive gravitation, and about the larger centres of gravitation this accumulation must be proportionately more considerable. Hence the sun would be imbued with, and surrounded by, a more dense medium of the luminiferous and electric matter than the earth. Still, from its probable constitution, [$\overline{M}\circ^2$, it would be less under the influence of gravity than molecular matter, such as our atmosphere [$\overline{M}\circ$, in the ratio of $\frac{1}{99}$ to 1; which taken in connection with the known velocity of its its impulses, 192.500 miles per second, enables us to comprehend how it can fill the immense measure of space occupied by the fixed stars.

121. Since, therefore, the luminiferous medium must be more dense at the surface of the sun, than at the surface of the earth; it would necessarily follow, that a proportionately greater amount of the momentum emanating from the sun, would travel off impulsively in that medium. This circumstance taken in connexion with the very elevated temperature that, I have shown, must pertain to the sun; or with the fact, that though an equal space on the surface, 26.4 times more momentum must in the same time escape from the sun than from the earth, clearly ena-

bles us to comprehend the probable causes of the sun's luminosity. When we behold the multitude of fixed stars, that send their impulses of light to us, from immeasurably distant points in space, we are by analogy impressed with, the conviction, that each is some enormous solar sphere, vieing with or perhaps exceeding in magnitude our sun. For if very much smaller, they could not be thus luminous.

122. Innumerable as may be the modifications of impulse in the $\overline{M}\supset^2$ medium, our sense of vision can take cognizance of only a limited range of these modifications. From all surfaces of all molecular and visible bodies, must at all times emanate impulses in the $\overline{M}\supset^2$ medium. Comparatively little of this momentum do we recognize as light; yet oftentimes we may perceive the effect of such invisible rays, in sundry electric, magnetic and chemical phenomena; and especially in the increase or diminution of momentum thereby induced in molecular bodies, as evinced by a change of temperature.

123. We will now inquire if the $\overline{M}\supset^2$ impulses, originate solely at the surface of the sun, or whether they are essentially derived directly from the sun's mass, being transmitted through the surface. And here without dwelling long, considering the density of the $\overline{M}\supset^2$ medium which must pervade the sun, it is highly probable that to the total amount of $\overline{M}\supset^2$ impulses emanating from the sun, every molecular particle in the sun's mass, directly contributes. Hence the radiation from the sun, must proceed, not merely from the surface, but also from the interior mass. Hence the intensity of the light and heat of the sun, as emanating from any particular part of the disc, might be expected to be greater or less, somewhat in proportion to the amount of the sun's mass lying in the special direction of the ray. Whereas if the solar radiation originated at the surface, the centre of the disc should be least, and the margin the most productive in light and heat.

124. Bouguer determined (Bowditch's Laplace, IV. 556) that the centre of the sun's disc is most, and the margin least luminous. The light contributed from a point, one-eighth the sun's diameter from the margin, bears in respect to intensity, to the light from the centre, the ratio of 35 to 48. Now if the line of vision be carried continuously through the sun's mass, in the direction of these two points, it will by calculation be seen, that the chord of an arc which the first will describe, will bear to the sun's diameter which the second will describe, the ratio nearly of 35 to 52, which is too close an approximation to the ratio of intensity before stated to be accidental.

CENTRAL HEAT OF THE EARTH.

125. For the present, I merely advert to the high temperature, probably existing in the interior of the earth, for the purpose of saying, that I think it can be shown to depend on causes now in operation. That a greater proportionate amount of molecular momentum should be possessed by the interior molecules of the earth, would seem fairly to result from the laws of dynamical equilibrium;—from the relation of such molecules to others more nearly superficial; to the $\overline{M}\supset^2$ medium investing the earth, and to the ponderefacient impulses.

POLARITY.

126. When we enquire into the habitudes of those enormous spheres revolving in space, properly denominated stellar atoms, the sun, planets,

&c., we find they rotate in a regular manner upon axes. So when we study the phenomena, presented by the integrant molecules of bodies within our reach, we find abundant evidence to warrant the belief, that they too, though incomprehensibly minute, are incessantly performing movements of rotation.

127. Thus in their rotary motion, the atoms of matter may possess untold and incalculable stores of momentum, respecting which we can become indirectly informed, by interpreting aright such natural phenomena as are more or less dependent thereon. The explanation of many important physical facts, is, in my opinion, to be found by studying the peculiar relation of forces due to molecular rotation or polarity.

128. I have lately made the following experiments :—Cause two spheres or circular discs to rotate in the air rapidly on their axes, leaving their centres of gravity free to move, and it may be seen that, mediately, though the passive agency of the air, each sphere or disc acquires a ring of repulsion and two poles of attraction ; and the discs or spheres, according to the positions in which they are presented to each other, will either mutually attract or repel each other. Here induced currents of air tend to coalesce in obedience to pressure indirectly caused, and on the principle of least action. So, likewise, one of these whirling discs, brought near the other at rest, will induce rotation and consequent attraction or repulsion in the latter.

129. Although the medium air, passively and reciprocally producing the aforesaid attractions and repulsions, is incomparably more gross than the medium of light and electricity, yet in the latter, analogous facts are observable. Neighboring currents of electricity moving in the same direction, on conductors free to move laterally, will tend to coalesce into one, for they will then encounter less resistance or friction in their movement. If $d=$ the diameter, $pd=$ the periphery, and $ad^2=$ the sectional area of each separate current; then $2\ ad^2=$ the sectional area, and $\frac{p}{a}\times\overline{2ad^2}|^{\frac{1}{2}}=$the periphery of the combined current. Now, $2pd$: $\frac{p}{a}\times\overline{2ad^2}|^{\frac{1}{2}}$: : $2 : \overline{2}|^{\frac{1}{2}}$, so is thefriction offered the two currents, to the friction offered the combined current. That is, more than one fourth the friction is thus avoided.

130. In accordance with these views, electro-dynamics may be considered as a branch of physics, embracing phenomena not dependent upon the occult for explanation. And although much remains to be developed by future research, yet I conceive so much is already known that we may begin to entertain rational notions. Mr. Wheatstone found that the electric fluid travels along good conductors nearly 200,000 miles per second. Such a current being sent through a coiled conductor, repeatedly around a rod of iron, obviously induces the electric medium which pervades the iron to run in corresponding circular currents. This revolving influence is probably felt by the integrant molecules of the iron itself, and must be propagated by induction from particle to particle, to the extremity, of the iron rod. If another piece of iron be presented near said extremity a similar dynamical condition is induced therein in like manner. And as, by the experiments with the whirling discs, we know that bodies rotating on axes that nearly correspond in place and direction, mutually

attract by the agency of the intervening air; so here molecules by the like means may mutually attract, through the agency of the refined and attenuated electric fluid, which, like air, constitutes a material medium, though differing widely in tenuity.

CONDITIONS OF AGGREGATION ASSUMED BY PONDERABLE MATTER.

131. The *solid*, *liquid* and *gaseous* conditions are observed to pertain to ponderable matter. The forces concerned in producing and maintaining these three states of aggregation, are what I call molecular attraction and repulsion, and polaric attraction and repulsion.

SOLIDS.

132. In solids, all these forces are manifestly operative. *Crystalization* is essentially due to the polaric forces. Molecules operating on each other by poles of attraction and rings of repulsion, would necessarily arrange themselves, if free to move, in obedience to those forces, and hence would primarily tend to approximate and string themselves along in the direction of the poles; producing a crystalline fibre, and at the same time divesting themselves of that freedom to move from place to place among themselves, which constitutes fluidity.

133. A sphere may simply rotate on a fixed axis, when there would ensue, the sphere being enveloped in an appropriate medium, an equatorial ring of repulsion, and two poles of attraction. A sphere may rotate around a moveable axis, the axis itself rotating; and thus it is possible that an infinite variety of regular movements may be given to the axis. It is at least probable, that in the different chemical molecules, different movements of the axis of rotation obtain, thus conferring diverse qualities of attraction and repulsion, and giving origin to the numerous varieties of crystalline form.

134. Specific chemical qualities are probably thus mainly attributable to modifications of the polaric forces. In a compound molecule, the component atoms probably retain essentially their peculiar polaric forces, while as a result of their union, the compound molecule may possess a special polarity, though of a less energetic character.

LIQUIDS.

135. In liquids, like water, oil, etc., the molecules seem free to take any mutual position. If the polaric forces are in any degree operative, which is, perhaps, not impossible, they are evidently disguised by the prevailing forces of molecular attraction and repulsion.

136. To determine the amount of molecular attraction exercised transversely to a plane of given dimensions, in liquids,

Let $d=$ the distance between two adjacent molecules.

Between any two molecules the force of right lined impulsive attraction varies as $\frac{1}{d^2}$. (¶ 58.) The number of molecules presenting themselves to the plane must also vary as $\frac{1}{d^2}$. Hence the effective amount of attraction arising from these circumstances alone must be as $\frac{1}{d^2}\times\frac{1}{d^2}=\frac{1}{d^4}$. But as d varies, so the extent and amount of $\overline{M}\circ^2$ matter enveloping the molecules must vary (¶ 106) in some dependant ratio. Now it seems probable that molecular attraction may arise mainly from impulses in the $\overline{M}\circ^2$ medium. Each molecule must hold around itself, by virtue of

attraction induced by subordinate media, ($\overline{M}\ominus^3$, $\overline{M}\ominus^4$, &c.,) a special atmosphere of $\overline{M}\ominus^2$ matter, which being affected by the $M\ominus^2$ right lined impulses, would necessarily affect in like manner the $M\ominus$ nucleus. The variation of the force of molecular attraction from this cause alone between two adjacent molecules, as a maximum, would be directly as d^2. And multiplying $\frac{1}{d4}$ above, by d^2, the expression for the law of molecular attraction in liquids considered in reference to a constant plane, becomes $\frac{1}{d^4}\times d^2 = \frac{1}{d^2}$.

In paragraphs 71. 74, 76 and 98, where I have determined certain maximum and minimum molecular values, I have therefore used the expression $\frac{1}{d^2}$ for the law of attraction. Yet it can be made apparent that where molecules recede very considerably, as in the conversion of liquids to gases, the amount of attraction through a given plane varies according to a constantly and regularly varying law. Commencing with a minimum variation of $\frac{1}{d^2}$, the law of variation must finally become $\frac{1}{d^4}$, as a maximum or extreme, as above set forth.

GASSES—AERIAL MEDIA.

137. Molecular repulsion, as before explained, (¶ 68), is generally regarded as the only force operative among the molecules of aerial fluids. It seems a very fair inference, however, that molecular attraction does act, though in a very feeble and inappreciable degree, which accords with the law of its variation, $\frac{1}{d4}$ before expressed. (¶ 136). By calculation in accordance with this law, the force of molecular attraction, as exercised through a plane of given dimensions in water, is 11880 times greater than that exercised through a plane of equal dimensions in air. The force of repulsion in gases, therefore, appears to be equilibrated by external pressure, or by the weight of the atmosphere itself.

FLAME APPLIED TO AN EXPLOSIVE GASEOUS MIXTURE.

138. Why should the application of flame to an explosive gaseous mixture, determine sudden chemical union: and why should this union be accompanied with a great and sudden increase of temperature or molecular momentum?

139. To offer rational answers, it will be requisite to suppose that each individual molecule of the gases concerned in the chemical union, consists of two or more smaller molecules, held near each other by polaric attraction. Let us suppose we have a mechanical mixture of two gases, capable of entering into chemical combination, say O and H; and further that each gaseous molecule of O and H consists of two equal atoms o, o' and h, h' bound together by a feeble polaric attraction. It must be admitted, that under equal circumstances the polaric attraction which an atom of O and H would exert on each other, is stronger than the polaric attraction subsisting between the two atoms of O, or the two atoms of H; the possibility of which can be shown. In their ordinary oscillations, the nuclei O and H do not approximate each other sufficiently close, for the efficient reciprocal exercise of polarity. But should any ex-

traordinary force be given to the mutual collision of O and H, in any part of the gaseous mixture, then o, and h, and o' and h' enter into molecular union. That is $o+o'$ and $h+h'$, becomes $o+h$ and $o'+h'$. It is easy to demonstrate how after this union, polaric repulsion might operate between the new molecules $o+h$ and $o'+h'$; and how consequently their velocities on receding would be greatly increased above the normal rate; whereby they could in turn impel other molecules of O and H into close collision, with like consequence of chemical union. Thus the action once begun, would propagate itself with more than the velocity of sound through the whole gaseous mixture. Here the increase of molecular momentum, developed during the act of union, must be derived from that incalculable store of momentum, possessed by the primary $\overline{M}\circ$ atoms in their movements of rotation. Now a tip of flame, or any analogous cause, serves merely to commence the process of union by giving to comparitively few of the molecules, the requisite velocity, much in the manner above set forth.

CATALYTIC ACTION.

140. By catalytic action, chemists generally mean to express the influence which a body sometimes exerts in facilitating or causing chemical action, without itself suffering any chemical change. Though this is apparently a very recondite subject, yet I am of opinion, that in every known case of catalysis, so called, a more or less satisfactory explanation may be given.

141. It is well known that the clean surface of platina, and other metals in a less degree, will determine the union of oxygen and hydrogen in a gaseous mixture. I have not space to enlarge upon these matters, and will therefore only remark that primarily the gases may be condensed upon the surface of the met al by the polaric attraction of the metallic molecules, and thus brought to combine. The polaric repulsion developed as before described (¶ 139.), as a consequence of the chemical union, would, as the process went on, tend to increase the molecular momentum thereabouts; and should this in the platinum, attain sufficient intensity; in other words, should the platinum became hot enough, then conjointly with the said polaric repulsion, it would impel some of the gaseous molecules with sufficient force against neighboring molecules, to induce the commencement of chemical union in the uncondensed gaseous mixture itself; and hence might ensue an explosion, as if primarily caused by flame.

CONCLUSION.

142. In concluding this memoir, I would observe that there are many topics, embracing much relevant matter, not herein even hinted at. I regret that a want of the requisite time and space should exclude them. Yet having drawn up this sketch in the midst of diverse and imperative duties, I fear that as it is, I shall hereafter find in it more than enough to modify and amend. I trust, however, I am wedded to no opinions which I will not promptly relinquish, when they be clearly shown to be untenable.

143. Deeply impressed with the conviction, that all the current physical phenomena of the universe are but rational and regular sequences from rational and regular causes, I have discarded the idea of occult and inherent qualities. Where the relation of things seem occult and incompre-

hensible, I have uniformly ventured to infer that they merely seem so, because the true and essential relations have not yet been developed. When we look abroad into the workings of nature, few, comparatively, are the physical objects and relations which we truly comprehend; and countless, those which to us are dim and distant forms; admonishing us of our weakness, and of our infinitely small importance in the grand system of the universe. But let us not despair. For since we see that neither matter nor motion admit of natural annihilation, but that both possess the passive attributes of endless perpetuity; let us exult in the firm conviction, which by parity of reason forces itself upon us, that the gift of the Divine Being also,—that more subtile portion of ourselves which thinks, remembers and reasons, is destined to immortality.